NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF: GP

March 29, 1971

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned
U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,367,271

Corporate Source : NASA PASADENA OFFICE ~~Western Operations Office~~

Supplementary
Corporate Source :

NASA Patent Case No.: XNP-04731

Gayle Parker

Enclosure:
Copy of Patent

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FACILITY FORM 602

NASA-HQ

Feb. 6, 1968 R. E. WILSON 3,367,271

AUTOMATIC PUMP

Filed March 7, 1966 3 Sheets-Sheet 1

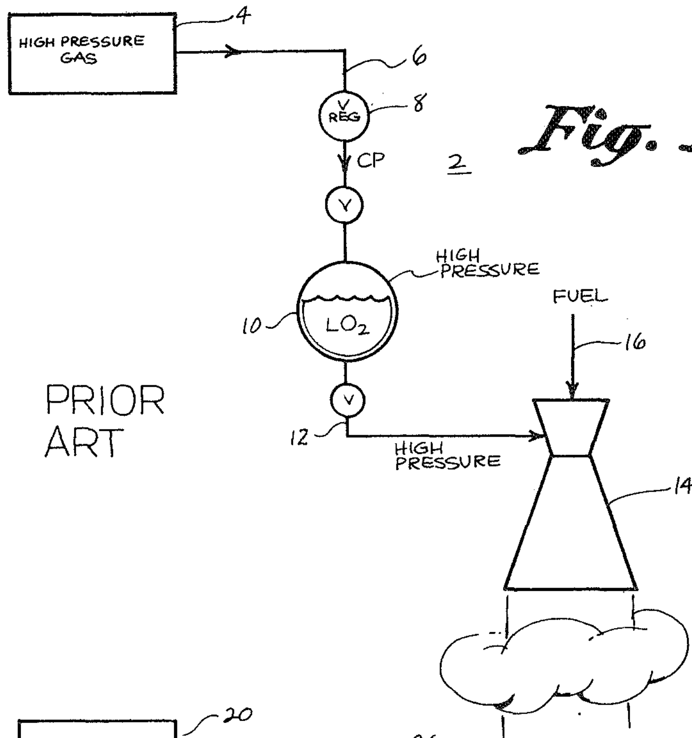

Fig. 1

PRIOR ART

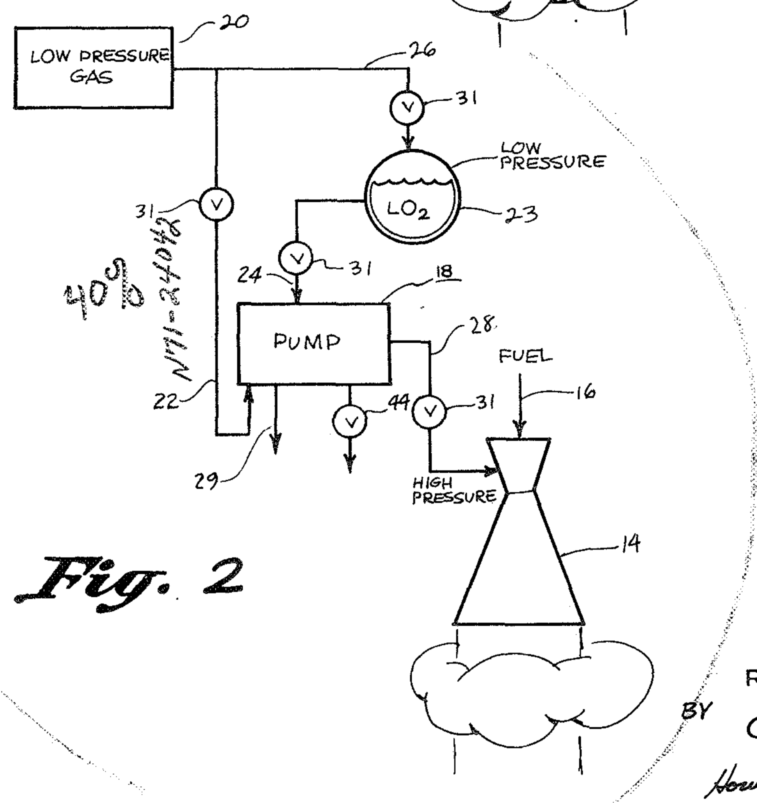

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Fig. 2

INVENTOR
ROBERT E. WILSON

BY

ATTORNEYS

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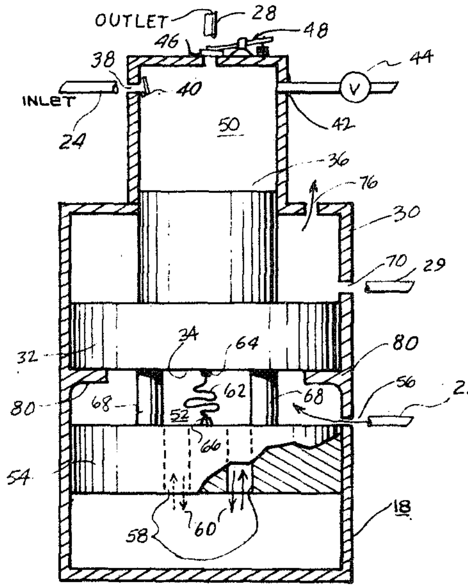


Fig. 3

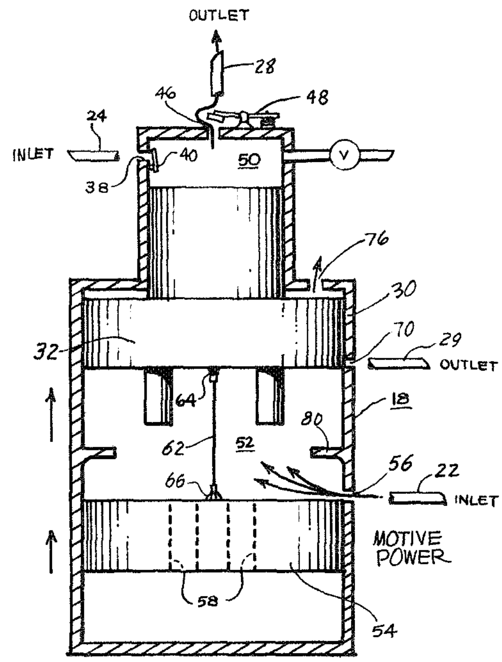


Fig. 4

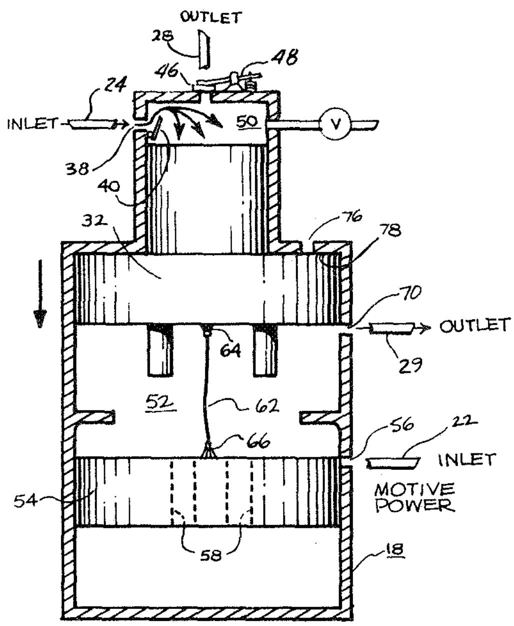


Fig. 5

INVENTOR
ROBERT E. WILSON
BY Olson & Cary
Howard B. Schechman
ATTORNEYS

Feb. 6, 1968 R. E. WILSON 3,367,271

AUTOMATIC PUMP

Filed March 7, 1966 3 Sheets-Sheet 3

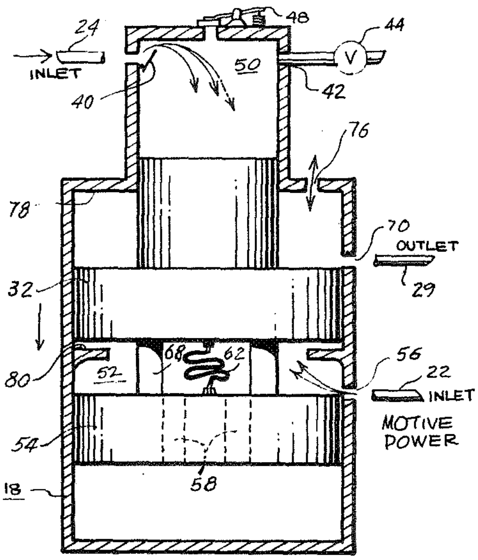
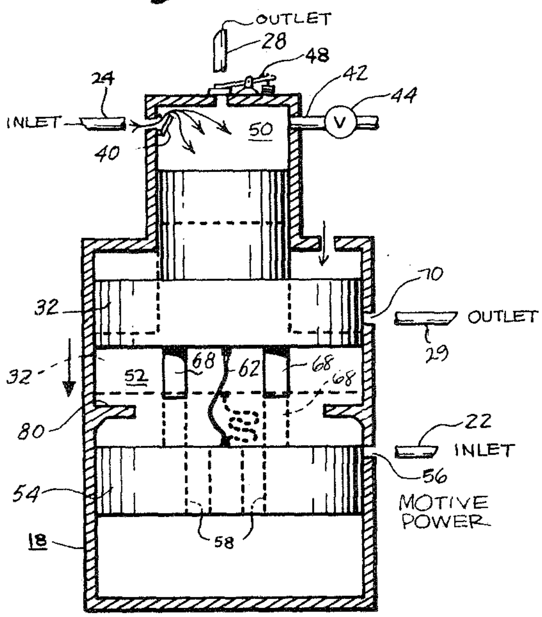


Fig. 7

Fig. 6



INVENTOR
ROBERT E. WILSON

BY

ATTORNEYS

United States Patent Office

3,367,271
Patented Feb. 6, 1968

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3,367,271
AUTOMATIC PUMP

Robert E. Wilson, Santa Monica, Calif., assignor to the United States of America as represented by the Administrator of the National Aeronautics and Space Administration

Filed Mar. 7, 1966, Ser. No. 534,966
12 Claims. (Cl. 103—48)

ABSTRACT OF THE DISCLOSURE

This invention relates to a piston-operated pump. The pump includes two pistons interconnected by a lost motion connection. The first piston does the pumping. The second piston is freely movable relative to the first piston. The second piston covers and uncovers the motive fluid inlet and outlet ports, in response to movement of the first piston. The pump operates automatically and continuously when once started.

This invention relates to a pump, and more particularly to an automatically reciprocating, high pressure pump that can be employed with cryogenic propellants used in a spacecraft.

As is well known, the propellants used in a spacecraft are normally carried in a cryogenic state. It is also conventional to provide positive means of feeding the propellants to the spacecraft's engines, rather than to depend on gravity. One conventional way of feeding propellants is to provide individual tanks containing a gas at a high pressure and to use this gas to pressurize the propellant containers. A high pressure gas must be employed because the gas pressure drops rapidly as the gas is used to pressurize the propellant containers.

However, there are a number of problems involved in the use of a high pressure gas. The high pressure makes it necessary to make the elements of the propellant feed system, such as tanks, containers, piping, and valves of heavy weight material so they will have sufficient strength to withstand the high pressures. This extra weight decreases the efficiency of the spacecraft. Or, to put it another way, the spacecraft could make longer flights on the same amount of fuel if it did not have to carry the additional weight.

There is another problem where high pressure gas is used. A large portion of the gas carried in the pressurization tank cannot be used when its pressure drops below that needed to feed the propellants. To explain the above, assume that a pressure of 3500 pounds per square inch (p.s.i.) is needed to pressurize a cryogenic propellant container of liquid oxygen, for example. Also assume that it is necessary to use gas at a pressure of 5000 p.s.i. in the pressurization tank. The pressure of 5000 p.s.i. in the pressurization tank can only be reduced to 3500 p.s.i. Beyond that point, the gas pressure will be too low to maintain the oxygen propellant container sufficiently pressurized. Thus, while the pressurization tank contains gas pressurized to 3500 p.s.i., it can no longer be used and represents dead weight. At this point another pressurization gas tank must be used. Due to the above, the spacecraft must carry a number of pressurization tanks to assure that there will be sufficient gas pressure to feed the propellants during a space mission. This additional weight also decreases the efficiency of the spacecraft.

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With the above problems in mind, it can be seen that it would be advantageous to use a relatively low pressure gas for pressurizing. This would permit the various elements of the feed system to be made of lighter material and would increase the efficiency of the spacecraft. It would also be an advantage to use more of the pressurizing gas rather than only a portion of it. Thus fewer pressurization tanks would be needed and this resultant savings in weight would also increase the efficiency of the spacecraft.

A system constructed according to the principles of this invention, as discussed hereinafter, is capable of employing a relatively low pressure gas to provide positive means for feeding a cryogenic propellant fluid. Additionally, the system is capable of using a greater portion of the pressurization gas than could be used previously.

The above is accomplished by providing a low pressure, gas-driven reciprocating cryogenic pump to increase the pressure of the cryogenic fluid so it can be fed to the spacecraft's engines.

Essentially, the pump comprises a housing containing a differential piston that is freely moveable within the housing. The housing is also provided with cryogenic fluid intake and outlet ports, as well as pressurizing gas intake and outlet ports. These ports are so positioned that cryogenic fluid will be admitted to one side of the piston and pressurizing gas will be admitted to the other side of the piston.

The piston is moved by the pressurizing gas during the compression stroke and compresses the cryogenic fluid to the desired pressure. When the cryogenic fluid has been sufficiently compressed, a pressure release valve opens to connect the cryogenic fluid outlet port with the spacecraft's motor. On the intake stroke, the pressurizing gas on the other side of the piston is vented to atmosphere. The pump then employs the cryogenic fluid, which is at a pressure greater than atmospheric pressure, to move the piston back for the start of the compression stroke again. The piston operates through a lost motion connection and a control member to open and close appropriate ports in the housing so the pump operates automatically.

The pump is made with few moving parts, and has a long life that makes it suitable for long space missions. Also, since the pump has few parts, it will be easy to manufacture, and thus relatively inexpensive. The pump is explosion-proof so it can be used with explosive propellants, and it can be used where other forms of power, such as electricity, are unavailable or undesirable.

With the foregoing in mind, it is generally an object of this invention to provide a pump that can be used with cryogenic fluids.

It is another object of this invention to provide a pump that can be operated by a pressurized gas where electricity or other means of power are not available or desired.

Another object of this invention is to provide a pump that can be used in a spacecraft to pump cryogenic propellants.

Another object of this invention is to provide an automatic pump that has long life, very few parts, is easy to manufacture, and is explosion-proof.

Other objects and advantages will appear from the following description considered in conjunction with the accompanying drawings wherein:

FIG. 1 shows a portion of a prior art spacecraft's propellant feed system;

FIG. 2 shows a portion of the same propellant feed system utilizing the pump of this invention; and

FIGS. 3–7 are enlarged views of the pump of this invention, with certain portions in section showing the pump in some of its positions as it completes one cycle of operation.

DESCRIPTION

In order to provide a better understanding of the operation and construction of the pump a prior art, high pressure feed system for a spacecraft will first be described. The low pressure feed system employing the pump will then be described. Finally, the specific construction of the pump and a review of its operation will follow.

Referring to FIG. 1, there is shown a simplified portion of a prior art, high pressure feed system **2** for a spacecraft. Various values and controls have been omitted as these are not relevant to an understanding of the system.

In general, the feed system includes tank **4** containing high pressure gas, as, for example, nitrogen. This gas is fed through line **6**, containing valve **8** of the constant pressure regulator type, into container **10** containing a cryogenic propellant. Valve **8** operates to maintain a constant pressure in container **10**. The propellant in container **10** may be an oxidizer, for example, liquid oxygen.

The high pressure gas from tank **4** is used to pressurize container **10**, and pressurized oxygen from container **10** is in turn fed through line **12** to the spacecraft engine, shown as rocket motor **14**. In addition to the oxidizer, fuel is fed through line **16** to motor **14**. The fuel feed system is not illustrated since it is similar to the oxidizer feed system.

In the prior art construction shown in FIG. 1, gaseous nitrogen tank **4** is generally pressurized to approximately 5000 p.s.i. This high pressure acts on the elements of the feed system, such as line **6**, valve **8**, and liquid oxygen container **10**. These elements must be built to withstand this high pressure and therefore must be made of heavy, high strength materials. Further, a number of pressurizing tanks **4** must be provided for long space missions, and each tank adds additional weight to the spacecraft.

The low pressure feed system employing pump **18** will now be described. Referring to FIG. 2, there is shown a feed system, like FIG. 1, but illustrating how the pump of this invention can be used in a spacecraft to overcome some of the problems in the prior art high pressure system. Like parts in both figures are similarly labeled. As will be noted, the feed system now includes pump **18**.

Pump **18** obtains its motive power from a low pressure fluid such as gaseous nitrogen carried in tank **20**. Low pressure gas is fed through line **22** to pump **18**, while cryogenic fluid is fed from container **23** through line **24**, also to pump **18**. Tank **20** is also connected by line **26** to container **23** to pressurize it so there will be a positive pressure to feed the cryogenic liquid to pump **18**. The pressure of the cryogenic propellant is increased in pump **18** to a selected higher pressure and is then fed through line **28** to rocket engine **14**. The gas leaves pump **18** through exhaust line **29**. Various cut-off valves **31** may be provided in the lines for control purposes.

The pressure in tank **20** may now be in the range of 500 p.s.i., for example, as compared to 5000 p.s.i. in tank **4** of the prior art high pressure feed system. A much lower pressure can now be used because the pump can operate as a pressure intensifier by varying the driving and driven diameters of the piston, as will be described further on.

While the specific construction of the pump will be described below, it will be generally noted that in this system there is only high pressure in line **28** leading from pump **18** to rocket engine **14**. All the remaining components, valves, lines, containers and tanks are at a relatively low pressure. Since lower pressures are now employed, the heavy components previously needed to withstand the high pressures can now be replaced by lighter weight components. Further, the pump permits the use of a greater portion of the pressurizing gas, since, as noted above, the pump can operate as a pressure intensifier and can operate to a much lower pressure drop.

It will also be noted that if desired, low pressure tank **20** may be omitted entirely and a line containing a heater may be connected from oxygen container **23** to line **22** of the pump, and a heater connected in the line. The heater would operate to boil the liquid oxygen and thus form a gas to operate the pump.

How the pump of this invention can be advantageously used in a spacecraft has just been described. The specific construction of the pump will now be explained.

Referring to FIG. 3, pump **18** includes a housing **30** that contains a freely moveable piston **32**. Piston **32** looks like a top hat. It contains a large lower driving surface area **34**, and a smaller upper driven surface area **36**, to provide a differential area piston. The difference in areas **34**, **36** permits piston **32** to operate as a pressure intensifier, and thus exchange a low pressure and large area for a small area and a high pressure.

Housing **30** also includes a propellant inlet port **38** to admit low pressure cryogenic propellant fluid from line **24**. A one way check valve **40** is connected in inlet port **38** to prevent the fluid from backing up.

Housing **30** also includes a cool down port **42** containing valve **44**. This port is used to cool the pump prior to start up. Valve **44** is opened to permit cryogenic liquid to flow from port **38** through the upper housing, and out port **42** to atmosphere. This cools the pump down so the cryogenic liquid will not boil. Once the pump is cooled, port **42** is permanently closed.

A propellant outlet port **46** serves as an exit for the high pressure cryogenic liquid. Outlet port is connected to line **28** leading to the rocket motor. Port **46** is on the same side of piston **32** as is inlet port **38**. Outlet port **46** contains a pressure responsive valve **48** that can be set to open when the pressure on the cryogenic liquid has been increased to a selected higher pressure. This valve may be a conventional spring-operated valve, for example, whose release pressure can be adjusted by varying its spring force, as is well known in the art.

Referring to FIG. 3, as piston **32** reciprocates, it divides housing **30** into a first chamber **50** above the piston to receive the cryogenic liquid, and a second chamber **52** below the piston to receive the gas. The volume of these chambers will vary as the piston reciprocates between a compression stroke shown in FIGURE 3 and an intake stroke shown in FIG. 5.

The admission of the gas to housing **30** is controlled by control means in the form of a blocking member **54** and a lost motion connection illustrated as flexible member **62**. Blocking member **54** looks like a piston and is circular in plain view (not shown). It is moveable in the housing in response to movement of piston **32**. The side surface of the blocking member operates to block and unblock gas inlet port **56** to control the admission of pressurizing gas into chamber **52**. Gas inlet port **56** is connected to line **22** leading to tank **20**. Flexible member **62** is fixed at end **64** to piston **32**, and is fixed at end **66** to blocking member **54**. Flexible member **62** will permit movement of piston **32** relative to blocking member **54**. Flexible member **62** has very little mass and therefore very low inertia. Piston **32** is provided with abutment members **68**. These project downwardly and are positioned to engage and move blocking member **54** when piston **32** moves downwardly.

Blocking member **54** is provided with a plurality of passages **58** extending through it. These passages permit the gas to pass through the member (as shown by arrows 60, FIG. 3) so the pressure on both sides will equalize. Thus, the blocking member will offer very little resistance to up or down movement.

A gas outlet or exhaust port 70 is positioned in the housing and is opened and closed as piston 32 moves past port 70 in moving through a complete cycle. Exhaust port 70 is connected to outlet line 29. When gas outlet port 70 is open (FIG. 5) gas in chamber 52 is permitted to exhaust from housing 30 through line 29 to the atmosphere. When piston 32 covers outlet port 70, the gas is unable to leave chamber 52.

Housing 30 also contains an air vent 76 in its upper wall 78. The vent prevents a vacuum from forming when piston 32 moves downwardly, and permits air trapped between the piston and wall 78 to escape when the piston moves upwardly. Housing wall 78 also serves as a stop to limit upward travel of piston 32 and stops 80 are provided in the housing to limit downward movement of piston 32.

OPERATION

The general construction of the pump has just been described, the mode of operation of the pump now follows:

The various positions that the pump moves through in completing one cycle of operation are shown in FIGS. 3 through 7. Referring to FIG. 3, assume first that the pump has been cooled down to prevent boiling. This is done by opening valves 40 and 44 and passing cryogenic liquid through upper chamber 50 of the pump. Once cooled down, valve 44 is permanently closed. Assume also that upper chamber 50 is now full of cryogenic liquid.

Piston 32 is shown at the start of the compression stroke. At this point, inlet port 56, that is connected to line 22 of pressurizing gas tank 20, is unblocked and admits gas into chamber 42 of housing 30. In this position, gas outlet 70 is closed by piston 32, cryogenic liquid inlet and outlet ports 38, 46 are closed, and flexible member 62, between piston 32 and blocking member 54, is slack. As the gas enters chamber 52, the pressure moves piston 32 upwardly, decreasing the volume of chamber 50 above the piston.

Referring to FIG. 4, there is shown a later intermediate position in the movement of piston 32 during the compression stroke. It will be noted that flexible member 62 has now been stretched taut, whereas it was slack before. Piston 32 will now pull blocking member 54 upwardly so that the piston and blocking member at this point will move as a single unit. As piston 32 moves upwardly, it increases the pressure on the liquid in chamber 50 until a selected pressure is reached, and then valve 48 opens in outlet port 46. As piston 32 continues to move upwardly, it forces the compressed liquid out of chamber 50 into line 28. The pressure of the liquid in chamber 50 in turn maintains check valve 40 closed to seal off cryogenic inlet port 38.

Referring now to FIG. 5, piston 32 is shown at the end of the compression stroke. This is also the beginning of the intake stroke. It will be noted that piston 32 has pulled blocking member 54 upwardly so that it is now blocking gas inlet port 56 and closes this port. Piston 32 has engaged wall 78 to limit its upward travel, and in addition, piston 32 has uncovered gas outlet port 70 so it is now open and leads to the atmosphere (or vacuum of space). This permits the gas in chamber 52 to escape.

When gas outlet port 70 is opened, pressure on blocking member 54 will move this member upwardly an additional amount to more securely close inlet port 56. This movement is due to pressure on the lower surface of blocking member 54 being, for a very short length of time, greater than the pressure above the blocking member. This difference in pressure is because a finite time is involved before pressure equalization can take place through openings 58 when outlet port 70 is opened. During this short period of time the higher pressure on the bottom surface of blocking member 54 will move it upwardly an additional amount.

At the end of the compression stroke, the pressure in lower chamber 52, since it has been vented to atmosphere, will now be less than the pressure in upper chamber 50. This will permit outlet valve 48 to close since there is now insufficient pressure to keep the valve open. Also, the pressure of the cryogenic liquid, in chamber 50, since it is greater than atmospheric pressure in chamber 52, will open inlet valve 40 to admit cryogenic liquid to start the intake stroke.

Referring to FIG. 6, there is shown piston 32 at two different positions in moving downwardly during the intake stroke. In the solid line position, valve 40 has opened and the cryogenic liquid now flows into chamber 50. The higher pressure in chamber 50 in turn moves free piston 32 downwardly toward the position shown in dotted lines. It will be noted that only piston 32 moves toward blocking member 54. Blocking member 54 will not move until abutment members 68 engage it. This position is shown in dotted lines in FIG. 6.

Referring to FIG. 7, piston 32 has almost reached the limit of its downward travel. Abutment members 68 have engaged the upper surface of blocking member 54, and now piston 32 and blocking member 54 move as a unit. As blocking member 54 is moved downwardly by piston 32, it is moved away from its position blocking gas inlet port 56. When the gas inlet port is unblocked, gas is again admitted to chamber 52 and since this will provide a higher pressure on the surface 34 of piston 32 will move piston 32 upwardly to increase the pressure of the cryogenic liquid in chamber 50. At this point, valve 40 will close as piston 32 moves upwardly, as shown in FIGURE 3, to complete the cycle. The pump will operate automatically, repeating the steps shown and described in relation to FIGURES 3 through 7.

SUMMARY

From the foregoing description it will be seen that the pump is extremely simple in construction and in operation. The internal moveable parts of the pump include blocking member 54, piston 32, and lost motion means 62. The pump operates automatically with these small number of parts. The moving parts of the pump have very low inertia and will be quick to respond to changes in direction of movement. Since there are very few parts to wear out, the pump will have long life and is suitable for space use. Additionally, it is relatively simple to build and therefore relatively inexpensive.

It will also be noted that the pump is explosion-proof since it does not contain anything that can start an explosion.

The pump is usable under conditions where gas is available and other forms of power are unavailable or undesirable.

Although the present invention has been described and illustrated with respect to a specific embodiment, it will be appreciated that various modifications and variations may be made without departing from the spirit and scope of the invention. Thus, while the pump has been described with respect to a cryogenic propellant feed system, it will be apparent that the pump can be used wherever its properties can be advantageously employed. Additionally, although a gas and liquid are used in the described embodiment, it will be apparent that any two fluids can be used, or even a single fluid. It will also be apparent to those skilled in the art that many types of lost motion connections can be used in place of flexible member 62, such as telescope or sliding joint connections, for example. It is therefore not intended to limit the invention except by terms of the following claims.

What is claimed is:

1. In an automatic pump

(a) a housing;

(b) a free piston moveable in said housing, between a first position and a second position;

(c) first fluid inlet and outlet ports in said housing, to admit and exhaust a fluid on a first side of said piston;

(d) a second inlet port in said housing, to admit fluid on the other side of said piston;

(e) a second outlet port in said housing for said last mentioned fluid, said port positioned to be closed and opened by said piston, said second outlet port being opened to exhaust said last mentioned fluid when said piston moves past said port to its first position; and,

(f) control means operative in response to the movement of said piston to close said second inlet port when said piston opens said second outlet port, and to open said second inlet port when said piston moves to said second position.

2. A device, as set forth in claim 1, wherein: said control means includes a blocking member that is moveable in said housing to open and close said second inlet port, and a lost motion connection that connects said blocking member and said piston and that operates to move said blocking member in response to movement of said piston.

3. In an automatic pump for fluids, the combination comprising:

(a) a housing;

(b) a free piston moveable in said housing between a compression stroke and an intake stroke;

(c) first fluid inlet and outlet ports in said housing to admit and exhaust a fluid to be compressed on one side of said piston;

(d) a second inlet port in said housing to admit a motive fluid on the other side of said piston;

(e) a second outlet port in said housing, positioned to be closed and opened by said piston, said second outlet port being opened to exhaust said motive fluid when said piston moves past said second outlet port at the end of its compression stroke; and

(f) control means operative in response to the movement of said piston to close said second inlet port when said piston opens said second outlet port, and to open said second inlet port when said piston approaches the end of its intake stroke.

4. A device, as set forth in claim 3, wherein:

(a) said piston is a differential area piston; and

(b) said first inlet and exhaust ports admit and exhaust said fluid from the small area side of said piston, and said second inlet port admits said motive fluid to the larger area side of said piston.

5. A device, as set forth in claim 3, wherein:

(a) said control means, that is operative in response to movement of said piston, includes a blocking member moveable in said housing to open and close said second inlet port.

6. A device, as set forth in claim 5, wherein:

said control means also includes a lost motion connection that connects said blocking member to said piston, said lost motion connection being constructed to permit said piston to move relative to said blocking member until said piston approaches the end of its compression stroke, said piston then moving said blocking member to close said second inlet port.

7. A device, as set forth in claim 4, wherein:

said control means includes a blocking member that is moveable in said housing, and a lost motion connection that connects said blocking member to the large area side of said piston.

8. A device, as set forth in claim 6, wherein:

said piston includes abutment means to engage and move said blocking member away from said position closing said second intake port.

9. A device, as set forth in claim 6, wherein:

said lost motion connection is a flexible member.

10. A device, as set forth in claim 3, wherein:

said housing contains a closeable port on the same side of said piston as said first inlet port, said closeable port permitting fluid to flow from said first inlet port through said pump and out said closeable port to cool said pump down prior to its operation when a cryogenic liquid is used in said pump so as to prevent boiling of said cryogenic liquid.

11. In a pump for cryogenic liquids, the combination comprising:

(a) a housing;

(b) a piston having a small area on one side and a larger area on the other side, said piston being moveable in said housing between a liquid compression stroke and a liquid intake stroke;

(c) a first inlet port in said housing to admit said cryogenic liquid into said housing on the small area side of said piston;

(d) a first outlet port in said housing positioned on the same side of said piston as said inlet port;

(e) a second inlet port in said housing, on the opposite side of said piston, to admit a motive fluid to the larger area side of said piston to move said piston to compress said cryogenic liquid;

(f) a second outlet port in said housing being positioned so it will be blocked by said piston until said piston reaches the end of its compression stroke;

(g) a blocking member moveable in said housing and connected to said piston through a lost motion connection, said piston moving said blocking member through said lost motion connection to close said second inlet port when said piston unblocks said second outlet port;

(h) said blocking member maintaining said second inlet port closed until said position reaches the end of the cryogenic liquid intake stroke, said cryogenic liquid moving said piston during said intake stroke while said blocking member maintains said second inlet port blocked; and,

(i) means carried by said piston to move said blocking member away from said position closing said second inlet port when said piston completes the intake stroke, so as to admit said fluid to start the compression stroke, to repeat the cycle.

12. In an automatic pump for cryogenic liquids, the combination comprising:

(a) a housing;

(b) a free piston having a differential area, said piston being moveable in said housing between an intake and a compression stroke;

(c) a first inlet port in said housing to admit a low pressure cryogenic liquid to be compressed to a higher pressure into said housing on the smaller area side of said piston;

(d) a first outlet port in said housing, on the same side of said housing as said first inlet port;

(e) a second inlet port in said housing to admit a gas on the larger area side of said piston, said gas being operative to move said piston against said lower pressure cryogenic liquid to increase the pressure of said liquid;

(f) a second outlet port in the side of said housing, and positioned to be closed by the side of said piston until the end of the compression stroke, said port on being opened permitting said gas to exit from said housing when said piston is at the end of its compression stroke;

(g) a circular blocking member moveable in said blocking member being connected to said piston by a flexible member, said blocking member being moved by said flexible member in response to movement of said piston reaching the end of the compression stroke to block said second inlet port as said piston opens said second outlet port;

(h) said piston being moved into position for the start of the compression stroke, by said low pressure cryogenic liquid during the intake stroke, while said high pressure inlet port remains blocked; and

(i) abutment means carried by said piston to engage and move said blocking member away from said position blocking said second inlet port, in response to said piston reaching the end of its intake stroke to open said first inlet port to repeat the cycle.

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ROBERT M. WALKER, *Primary Examiner*